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Composting of Mixed Yard and Food Wastes with Effective Microbes

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Graphical abstract

Abstract

Composting is one of the alternatives that can be used in waste management to control the increment of waste generation including that is in Universiti Kebangsaan Malaysia (UKM). However, a conventional composting is rarely applied due to the longer time consumed to reach maturity phase. This research is focus on the use of effective microbes (EM) that will accelerate the composting process hence composting can be an alternative to treat the problem of organic waste in UKM.This research which took 7 weeks of completion is intend on finding the best EM that can be used to accelerate the composting process. Two types of organic waste are being used in this composting process which is yard waste and food waste. Two EM are applied in this research which is Takakura EM and Fruit Waste EM. The parameters which include temperature, moisture content, pH value, C:N ratio, NPK (Nitrogen, Phosphorus, Potassium) value and heavy metals concentrationhave been examined. The composting methods applied in this research are composter barrel and rotary drum. Based on the result of observations and experiments after 7 weeks, all pH values for the composts are approximately at neutral value (7.0-8.0) showing that the compost has approached mature phase. For C:N ratio, all of the compost has reached a value of less than 20:1 which is suitable to be used for agriculture. NPK content for potassium is from 0.073 to 0.133 and for phosphorus is from 0.049 to 0.512. For heavy metals, all compost has low levels of heavy metals where it is safe to use for agricultural. Thus, it is concluded that the quality of compost for this research is good and EM Takakura is said to be the suitable solution in decreasing the time taken for composting.

Keywords: Composting; Yard waste; food waste; effective microbes

1.0 INTRODUCTION

According to the Solid Waste Management Act 2007 (Act 672), solid waste is defined as any unused material; material that is already broken, contaminated or worn-out that requires disposal; or material that requires disposal according to the Act or Authority. Solid waste is one of the three major environmental problems in Malaysia and plays a significant role in nature's ability to sustain life. Over 23,000 metric tons of wastes are currently produced each day in Malaysia, and this amount is expected to increase to 30,000 metric tons by the year 2020 because of the country's increasing population and development (Rancangan Malaysia Ke-9, 2006-2010). Less than 5% of this waste is recycled. According to statistics released by the Ministry of Housing and Local Government in 2001, 16,247 metric tons of waste was generated in Malaysia every day.

Integrated solid waste management is a system consisting of 6 elements: generation, storage, collection, transportation, biological treatment, and disposal. These elements are important to the concept of sustainable development in public health, economics, engineering, conservation, aesthetics, public awareness, and the environment. Biological treatment which consist of composting and anaerobic digestion arethe methods of recycling of organic waste, such as plant- and animal-based waste, to reduce the amount of waste disposedin the landfills. The natural process of decomposition of organic waste performed by EM produces compost that can be used as organic fertilizer in agriculture (PPSPPA, 2009).

An aerobic composting process occurs when conditions are optimized for the growth of aerobic microbes. Aerobic microbes require oxygen, water and food for the decomposition process.Thus, important parameters such as temperature, moisture content, pH and oxygen demand, must be controlled in order to obtain the best-quality compost. The optimum moisture content for composting is approximately 50-70% by weight, and the oxygen demand is approximately 15-20% from the air cavity. The required C:N ratio is approximately 30:1, and the compost quality is best when the final C:N ratio is between approximately 10:1 and 20:1 (University of Illinois Extension, 2007). Both carbon and nitrogen contents are important because they supply energy in the form of glucose molecules and nutrients in the form of protein molecules for the decompositionofmicrobes.

Aerobic composting requires the presence of oxygen for microbes decomposition (Day et. al, 1998). The final products of aerobic composting consist of CO_2, NH_3, water and heat.

Organic matter + O_2 + nutrients -----> new cells + semi-compost organic materials

$$+ CO_2 + H_2O + NH_3 + SO_4^{2-} + ... + heat$$

Anaerobic digestion is a decomposition of organic materials by anaerobic microbes that occurs in the absence of oxygen. Anaerobic digestion takes longer time than aerobic composting and produces a foul odor during process.The final products usually consist of CH_4, CO_2, NH_3, and acidic gases. The decomposed materials tend to be more acidic under anaerobic conditions. Thus, in this study, the type of biological treatment applied is aerobic composting.

Microorganisms, such as bacteria, fungi and actinomycetes,exert a major influence on the composting process. These microorganisms are categorized as chemical decomposers because they change the chemical structure of composted organic waste. EM is a concentrated brown solution that contains more than 80 microbe strains, primarily lactobacillus, photosynthetic bacteria, yeast, and ray fungi. EM also contains both aerobic and anaerobic microbes that exist at a pH of 3.5 (Higa, 1991), and it is widely used in agriculture, animal husbandry, aquaculture, wastewater treatment and solid waste treatment to increase the quantity and quality of the end products and to improve the treatment of certain contaminants (Higa, 1994).

The goal of this study was to investigate the effectiveness of EM in accelerating the composting process using composter barrel and rotary drum methods. These two methods are included to obtained the more efficient method for future composting process in UKM since both are differ in turning process which is for composter barrel, turning process is done manually and for rotary drum, turning process is done mechanically. The quality of the compost was investigated by measuring important parameters,such as temperature, moisture content, pH, C:N ratio, NPK value and heavy metal concentrations.

■2.0 METHODOLOGY

2.1 EM Preparation

2.1.1 Takakura EM (IGES, 2009)

Seed compost is created by mixing fermenting solutions and a fermenting bed. The fermenting solutions included 2 types of solutions. In this study, the sugared solutions (15 ml each) included fermented foods such as yeast, yogurt, unrefined soy sauce and fermented soy beans.The salted solutions (5 ml each) included fresh vegetables, such as eggplant, cucumbers and cabbages, and fruits, such as apples, grapes and oranges. The fermenting solutions were left for 3 to 5 days to allow the fermenting microbes to grow before being mixed with the fermenting bed, which consisted of rice bran and rice husks at a ratio of 1 m^3:1 m^3. This seed compost was left for 3 to 5 days before being mixed with the compost piles (IGES, 2009).

2.1.2 Fruit Waste EM

Fruit waste EM consists of 60% water and 40% fruit waste (fruit peels, fruit seeds, and rotten fruit) by volume. The EM was left for 3 to 5 days to allow for the growth of the microbes before being mixed with the compost piles.

2.2 Compost Material Preparation

Yard waste was collected at UKM and sent to the composting site to be shredded. The waste was shredded using a shredder from the Department of Development Management (JPP) with assistance from workers at the JPP. The food waste used for composting was taken from the cafeterias at Ibrahim Yaakub Residential College, Keris Mas Residential College, and Rahim Kajai Residential College in the late afternoon, between 3 pm and 4 pm, because the highest quantity of food waste was produced during that time of day.

2.3 Composting Process

A composter barrel and rotary drum were used for the composting process in this study. Both the composter barrel and rotary drum contain 4 compartments, and each compartment contains a type of compost with a unique composition. Tables 1 and 2 show the composition of the compost in each compartment of the composter barrels and rotary drums. Biodegradable and non-biodegradable plastics are included in the compost pile to observewhether they will degrade along with organic waste in composting process.

Table 1 Composition of compost in composter barrel

Bin	Composition
A	1:1 ratio of yard waste to food waste with Takakura EM; biodegradable plastic
B	1:1 ratio of yard waste to food waste with Takakura EM; non-biodegradable plastic
C	1:1 ratio of yard waste to food waste with fruit waste EM; biodegradable plastic
D	1:1 ratio of yard waste to food waste with fruit waste EM; non-biodegradable plastic

Table 2 Composition of compost in rotary drum

Bin	Composition
1	100% yard waste without biodegradable plastic
2	50% food waste and 50% yard waste without biodegradable plastic
3	50% food waste and 50% yard waste with ripped biodegradable plastic
4	50% food waste and 50% yard waste with unripped biodegradable plastic

2.4 Organic Waste Composition

The masses of the yard and food wastes were measured before depositing them into the composter barrel and rotary drum. The input of both yard waste and food waste are in ratio of 1:1 by volume. The amount of organic waste composted in the composter barrel and rotary drum is shown in Tables 3 and 4.

Table 3 Food and yard waste in the composter barrel

Bin	Weight (kg)		
	Garden waste	Food waste	Total (kg)
A	4.8	16.1	20.9
B	3.9	15.5	19.4
C	4.5	15.9	20.4
D	1.8	8.3	10.1

Table 4 Yard and food waste in the rotary drum

Bin	Weight (kg)		
	Garden waste	Food waste	Total (kg)
1	11.6	-	11.6
2	4.8	14.0	16.8
3	5.2	18.0	23.2
4	5.6	18.2	23.8

2.5 Composting Parameters

Laboratory tests were performed to investigate the parameters involved in composting: pH, moisture content, carbon to nitrogen ratio, heavy metal content and NPK nutrient content.

A moisture content test was performed to determine the percentages of water in the samples according to standard of ASTM E 989-88. According to Jeris and Regan (1973), the optimum moisture content for composting is between 50% and 70% by weight. The optimum moisture content obtained from the biodegradation of compost is between 50% and 70% (Richard et. al., 2002). The decomposition process can be performed successfully by microbes only if the moisture content is maintained between 40% and 60% (Cahaya et. al., 2009). For the moisture content test used in this study, the weight of the container with the sample is determined in advance and is referred to as the wet weight, W_1. Next, the container and sample are placed in a 110 °Coven for 24 hours to determine the loss of water from the sample. The samples are then weighed, and this value is referred to as the dry weight, W_2. The formula for moisture content is as follows:

$$\frac{\text{Wet weight of sample } (W_1) - \text{Dry weight of sample } (W_2)}{\text{Wet weight of sample } (W_1)} \times 100$$

The laboratory test used to determine the sample's pH value was performed with an electronic pH meter. Ten grams of the sample was diluted with 100 ml of distilled water, and the electrode was rinsed with distilled water before and after the measurements. The readings were taken three times to obtain a precise pH value.

To determine the carbon to nitrogen ratio, the test is according to standard of ASTM E 777-87 and E 778-87. The compost material was prepared and baked in a 70 °C oven for 24 hours. The sample was then allowed to cool and was ground into a powder. Two grams of the blended sample was placed in a small aluminum cone and tested in a CHNS-O analyzer instrument.

For determining amount of nitrogen, a 4500-NH_3 Ammonia Nitrogen test is being applied. The test consists of titration and distillation process on a diluted sample using Borate Buffer solution to determine the existent of ammonia nitrogen in the sample.

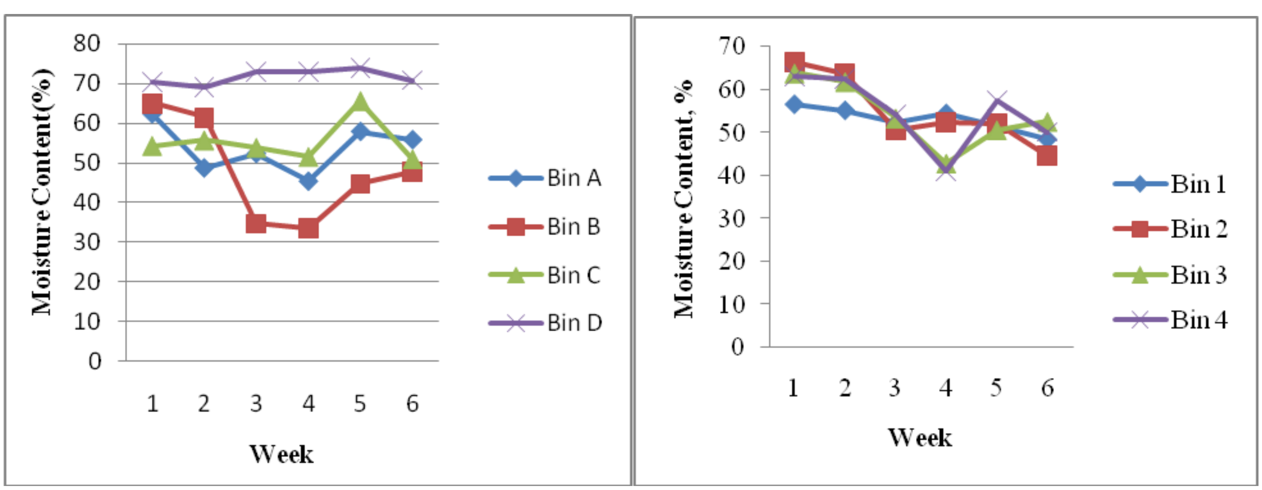
The amounts of potassium, phosphorus and heavy metals contents are determined using ICPMS test according to standard of APHA 5125 B. Sample is first diluted with nitric acid until the solution is almost clear then it is filtered with filter paper before tested using *Inductively Coupled Plasma-Mass Spectrometry* (ICPMS) machine for final results.

3.0 RESULTS AND DISCUSSION

3.1 Moisture Content

Figure 1 shows the moisture content of each bin included in this study. When the composter barrel was used, the moisture content of bin D was greater than that of bins A, B and C because the yards waste in the latter bins was dryer.Thus, the absorption of water from the yard waste reduced the moisture content in bins A, B and C.

When the rotary drum was used, the moisture contents of bins 2, 3 and 4 were high at the beginning of the study because of the addition of food waste. However, the moisture content of these three bins decreased because of the absorption of residual water content by the yard waste. The moisture content in bin 1 at the beginning of the composting process appeared to be lower because the waste used was yard waste only. The waste was watered to ensure that the waste's optimum moisture content (40-70%) was maintained.



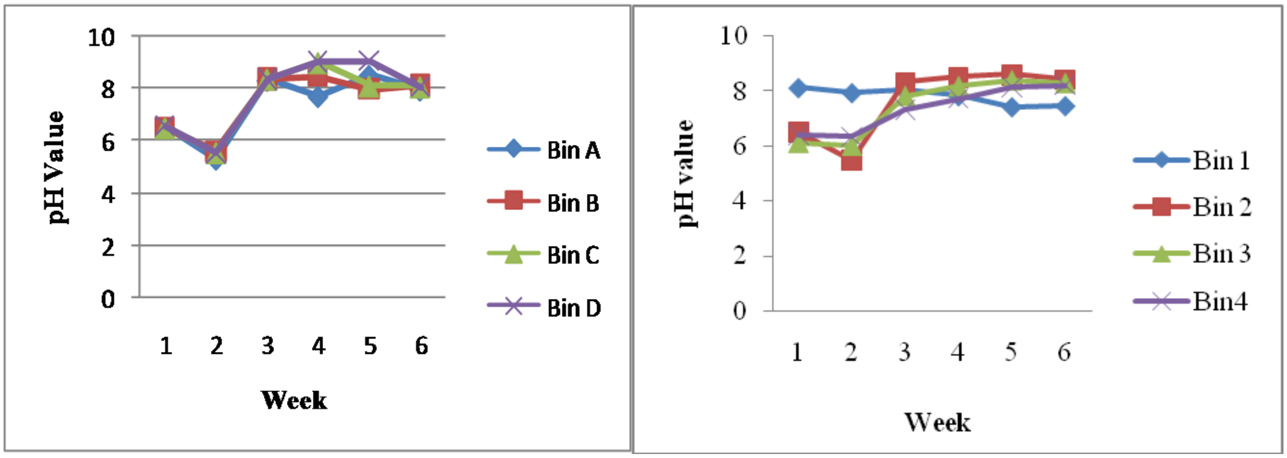
(a) (b)

Figure 1 Moisture content by week in the composter barrel (a) and rotary drum (b)

3.2 pH

According to Nakasaki *et al*. (1993), the optimum pH for the degradation of organic waste is in the range of 6 to 9, and when the compost enters its mature phase, the pH becomes neutral, approximately 7-8. Figure 2 shows that bins A, B, C and D in the composter barrel were acidic in their early, mesophilic phases. The pH then increased to between 8 and 9 in the 3rd week, when the composting process entered its thermophilic phase and decreased until it was almost neutral (7-8) during the 6th week, when the compost reached its mature state.

The pH values in bins 2, 3 and 4 in the rotary drum were low, indicating that the samples were acidic because of the food waste obtained from the cafeterias, which contained acidic materials. However, the pH values increased from the 2nd week onwards because of the decomposition of proteins and the elimination of carbon dioxide. By the 6th week, the compost in these bins had neutral pH values. The optimum pH value for composting is between 7 and 8 (Cooperband, 2000).

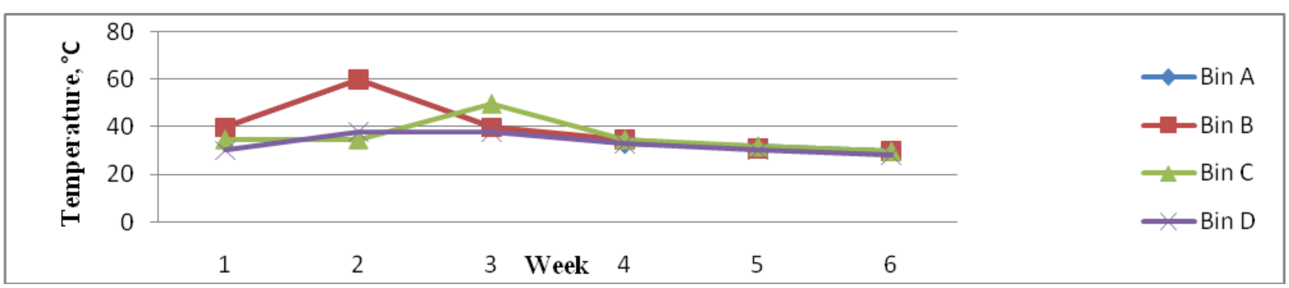


(a) (b)

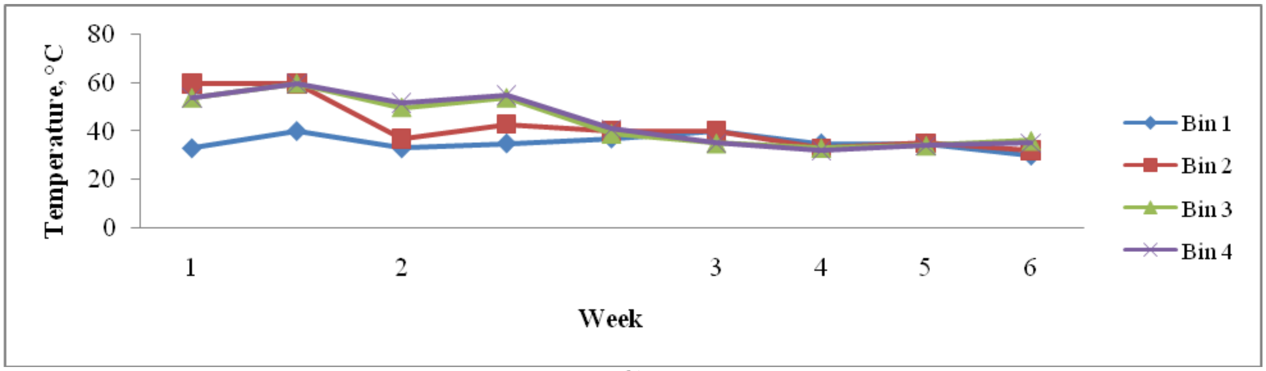
Figure 2 pH value by week in the composter barrel (a) and rotary drum (b)

3.3 Temperature

Figure 3 shows the temperatures measured inside the composter barrel and indicates that bins A and B reached their highest temperatures(60°C) during the 2nd week of composting. The temperature in bin C began to increase during the 3rd week and reached 50°C. The differences in how the temperature increasedbetween these bins illustrate one advantage of using Takakura EM over fruit waste EM. However, Bin Dexperienced only a slight temperature increase because the excess of moisture in this bin prevented it from reaching an optimum temperature, between 40°C and 70°C. The compost in bins 2, 3 and 4 of the rotary drum had the highest initial temperature readings and exhibited the onset of microbial activity. The compost in bin 1 had a relatively low initial temperature reading because it contained insufficient moisture, which retarded the onset of microbial activity. After a few days, as composts reached theirtermophilic phase, the temperature readings increased to more than 45°C in each compost bin. Subsequently, the temperature decreasedas the activity of the microorganisms slowed, indicating that the compost was nearing its mature phase.



(a)



(b)

Figure 3 Temperature by week in the compost barrel (a) and rotary drum (b)

3.4 Carbon to Nitrogen Ratio

According to Cooperband (2000), the optimum C:N ratio for compost is between 10:1 and 15:1. Compost products usually achieve a C:N ratio of 10:1 (Polprasert, 1996). The presence of carbon during composting assists microbes during the decomposition process, while nitrogen helps build microbial cell structures (Nor Afida, 2010). However, access to nitrogen leads to the emission of toxic ammonia gas, which can damage plant roots if the compost applied as fertilizer (Vines & Wedding, 1960). Carbon and nitrogen tests indicated that the C:N ratio in both bins are as in Table 5.

Table 5 C:N ratio

	Bin							
	Composter barrel				Rotary drum			
	A	B	C	D	1	2	3	4
C:N ratio	17:1	9:1	13:1	12:1	15:1	16:1	15:1	15:1

These results confirmed that the C:N ratio of all of the compost products was less than 20. Thus, the compost products were determined to be in their mature phases.

3.5 NPK nutrient and heavy metal contents

The compost productswill contain a small amount of NH3-N and nitrogen if 40% of the nitrogen is used during the composting process (Eghball & Gilley, 1999). Maintaining the moisture content within its optimum range during the composting process increases the concentrations of phosphorus and potassiumbecause of the volume reduction of organic waste (Agriculture and Rural Development, 2002). The nitrogen, phosphorus, potassium and heavy metal contents measured in this study are shown in Tables 5, 6, 7 and 8.

Table 5 NPK content in the composter barrel

Nutrient	Bin			
	A	B	C	D
Ammonia nitrogen, mg NH_3 -N/L	18.2	57.4	3.92	4.37
Potassium (K), ppm	0.240	0.124	0.187	0.512
Phosphorus (P), ppm	0.133	0.105	0.076	0.091

Table 6 Heavy metals content in the composter barrel

Heavy metal	Heavy metal content, ppm			
	Bin A	Bin B	Bin C	Bin D
Cadmium, Cd	0.0005	0.0005	0.0000	0.0010
Chromium, Cr	0.0115	0.0055	0.0070	0.0060
Copper, Cu	0.1165	0.0460	0.0205	0.218
Lead, Pb	0.0050	0.0010	0.0010	0.0035
Mercury, Hg	0.2085	0.0010	0.1085	0.0075
Nickel, Ni	0.0170	0.0140	0.0165	0.0155
Zinc, Zn	0.0955	0.0405	0.0110	0.0245

Table 7 NPK content in the rotary drum

Nutrient	Bin 1	Bin 2	Bin 3
Ammonia nitrogen, mg NH_3-N/L	2.24	20.16	28.00
Phosphorus, ppm	0.0730	0.0870	0.0760
Potassium, ppm	0.0490	0.1875	0.1125

Table 8 Heavy metals content in the rotary drum

Heavy metal	Heavy metal content, ppm		
	Bin 1	Bin 2	Bin 3
Cadmium, Cd	0.0000	0.0010	0.0000
Chromium, Cr	0.0080	0.0070	0.0075
Copper, Cu	0.0036	0.1285	0.0375
Lead, Pb	0.0015	0.0010	0.0010
Mercury, Hg	0.0000	0.0495	0.0020
Nickel, Ni	0.0170	0.0180	0.0165
Zinc, Zn	0.0565	0.1495	0.1115

3.6 Maturity of Compost Product

Semi-matured compost product requires undergoing curing process to obtained maturity phase. Curing process takes about 2 to 3 weeks and this process is significant in stabilization of components in compost product because unstable compost tend to release gases and organic acid that could harm the soil and plants if it is use as soil conditioner (IGES, 2009). According to Evanylo (2010), the best curing process takes about a month or more than few months.

Maturity of compost product can also be achieved by observation of physical parameters such as temperature, odor, texture and color. As the compost product is matured, the temperature will drop at certain degree which is in this case 30°C, and will be in fixed value even after applying turning process. Compost product will produce an earthy smell with the texture and color are similar to soil.

The acceptable size of a compost product to be used as soil conditioner is about 0.1 cm to 1.0 cm. As the compost products obtained from both composter barrel and rotary drum were rougher than the acceptable sizes, thus, the compost products should be shredded and sieved before being used or stored. Figure 4 and 5 show the compost products obtained from both composter barrel and rotary drum.

Figure 4 Compost products in composter barrel

Figure 5 Compost products in rotary drum

■4.0 CONCLUSION

This study demonstrates that the composting process is one of the feasible methods for reducing waste generation at UKM. Composting methods should be used because UKM produces large quantities of food waste and yard waste, and this study proved that the composting methods described here could be used on campus. It was also found that Takakura EM was the best EM for use in the composting process because it required a lesstime than Fruit Waste EM and produced good-quality compost. Biodegradable plastic was also amenable to being combined with the food waste in the composting process, making composting a simple procedure.

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